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Studies for the Loss of Atomic and Molecular Species from Io

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Studies for the Loss of Atomic and Molecular Species from Io

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I. Introduction

The general objective of this project is to advance our theoretical understanding of Io's atmosphere by studying how various atomic and molecular species are lost from this atmosphere and are distributed near the satellite and in the circumplanetary environment of Jupiter. The project is divided into well-defined studies described for the likely dominant atmospheric gases involving species of the SO_2 family (SO_2, SO, O_2, O, S) and for the trace atmospheric gas atomic sodium. The relative abundance of the members of the SO_2 family and Na (and its parent NaX) at the satellite exobase and their relative spatial densities beyond in the extended corona of Io are not well known but will depend upon a number of factors including the upward transport rate of gases from below, the velocity distribution and corresponding escape rate of gases at the exobase, and the operative magnetospheric/solar-photon driven chemistry for the different gases. This question of relative abundance will be studied in this project.

In order to address this question, we will undertake theoretical modeling studies for the distribution and time variability of these exospheric gases in Io's corona/extended clouds and thereby evaluate the importance of various physical processes that shape their relative abundances and escape rates. Our primary objective will be to study near-Io emission observations for O, S, and Na, most of which have already been acquired and some of which are scheduled to be acquired in 1996-1997 as part of the larger coordinated International Jupiter Watch Observational Campaign to support the Galileo mission. A secondary objective will be to continue the study of various larger-spatial-scale groundbased sodium and spacecraft (Voyager and Galileo) SO_2^+ observations in order to address related issues and to lay the groundwork for larger-spatial-scale O and S observations likely to be obtained in the near future. The proposed studies are of scientific importance in understanding (1) the atmosphere of the satellite, (2) the interactions of the magnetospheric plasma and the atmosphere, (3) the nature and composition of the heavy ion sources for the plasma torus, (4) the impact of these gases on the larger magnetosphere, and (5) the spatial distribution of these gases in the magnetosphere and beyond in the larger solar wind environment.

Near-Io observations for this project will be made available in four collaborative efforts established with

(1) F. Scherb of the University of Wisconsin-Madison who from groundbased facilities in 1990-1996 very successfully obtained synoptic observations of [O I] 6300 Å emission near Io and in 1996-1998 will continue these synoptic observations, search for [O I] 5577

Å emission, and add a new Fabry-Perot program element using the new WIYN telescope at Kitt Peak to obtain very-high spatial resolution images near Io in the [O I] 6300 Å and Na 5890 Å emission lines,

(2) G. E. Ballester of the University of Michigan who with HST has acquired cycle IV and will be acquiring cycle V observations for O and S near Io in various UV emission lines,

(3) L. M. Trafton of the University of Texas who has obtained in 1984-1989, and in his ongoing program in 1995 and 1996, groundbased observations for the north-south spatial distribution and spectral line shape of sodium (5890 Å, 5896 Å) emissions near Io, and

(4) N. M. Schneider of the University of Colorado-Boulder who obtained in 1987 from groundbased facilities an extensive set of observations for the east-west spatial distribution and spectral line shape of sodium emissions near Io, which exactly overlap the October 1987 observations of Trafton.

These near-Io emissions exhibit time variability with Io System III longitude and Io east-west location. The general three year plan of research for these studies is outlined in Table 1. Work scheduled for the first half of the first project year has been largely redistributed to the second half of the first project year in order to complete in a timely fashion a major research effort in our NASA sponsored Galileo Mission project which will be ending later in 1997. The research work performed in the first three bi-monthly periods is summarized briefly below.

II. Summary of Work Performed in the First Bi-Month Periods

Final paperwork for the project to begin was not received until well into the first bi-monthly period and was back dated to September 23, 1997, as a start date. No research work was performed in the first bi-month period. However, a well-received poster paper (Scherb et al. 1996) discussing the observations of [O I] 6300 Å emission near Io acquired in our ongoing collaboration with F. Scherb of the University of Wisconsin-Madison was presented at the Tucson AAS Division for Planetary Science meeting in October 23-26, 1996.

II. Summary of Work Performed in the Second Bi-Month Periods

Work undertaken in the second bi-monthly period was related to completing the final publication galley proof review and to correcting one figures for the paper entitled "Io's Sodium

Corona and Spatially Extended Cloud: A Consistent Flux Speed Distribution". This paper was written and submitted for publication in our prior NASA project for which this project is a continuation. The paper (Smyth and Combi 1997) is scheduled to appear in the March 1997 issue of Icarus. In addition, model calculations for SO_2 gas loss from Io were included in a larger poster paper (Smyth and Marconi 1996) presented at the San Francisco fall AGU meeting in December 15-19, 1996. These model calculations are particularly important in understanding the spatial distribution of SO_2^+ near Io which is expected to be available as particle and field observations by the Galileo spacecraft become available in the near future.

III. Summary of Work Performed in the Third Bi-Month Period

Work undertaken in third bi-monthly period was directed to considering how the System III longitude variation of the intensity of the [O I] 6300 Å emission near Io (which has one broad peaks near 180°) may possibly be related to the System III longitudinal asymmetry in the plasma torus ion temperature which has one broad minimum centered at 180°. A presentation (Smyth et al. 1997) to discuss a possible explanation for this System III longitude asymmetry in the plasma torus and how it may cause the System III longitude dependence in the [O I] 6300 Å emission brightness near Io will be presented at the Boulder "Magnetospheres of the Outer Planets Meeting" in March 17-21, 1997. The explanation of the this System III longitude asymmetry in the plasma torus was first presented (Smyth et al. 1996) at the Tucson AAS Division for Planetary Science meeting in October 23-26, 1996.

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Smyth, W. H. and M. L. Marconi, An Initial Look at the Iogenic Plasma Source During the Galileo Flyby of Io, EOS 77, F436, 1996.

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Smyth, W. H., M. L. Marconi, R. W. Spiro, and R. A. Wolf, Io Plasma Torus: Structure and Transport. BAAS 28, 1154, 1996.

Table 1

Three Year Plan of Research for Studies for the Loss of Atomic and Molecular Species from Io

Subject	Year 1	Year 2	Year 3
Studies for the SO_2 Family	Analyze HST (cycle IV) UV data for O and S and available [O I] 6300 Å synoptic data for O using the O, S, SO and SO_2 cloud models; improve model execution time, update chemistry and refine the model description of the plasma torus.	Analyze the HST (cycle V) UV data for O and S; initiate analysis of Fabry-Perot image data for [O I] 6300 Å and [O I] 5577 Å (if relevant); re-analyze Voyager SO_2^+ data; determine sources rates and constraints on O, S, SO and SO_2 for the individual studies.	Complete analysis of UV and optical data; undertake the comparative and collective assessment of the individual studies for O, S, Na and SO_2^+ to probe the nature of the atomic and molecular species in Io's atmosphere and their implications for the Jupiter system.
Studies for Sodium	Continue the analysis of the 1987 east-west emission data set; initiate analysis of the same-date 1987 north-south emission data; refine model description of the plasma torus; re-evaluate the Na source at Io for the directional feature.	Complete analysis of the 1987 east-west emission data set; undertake analysis of other select years of the north-south emission data set; determine the nature and variability of the Na source conditions and their dependence on east-west and System III effects; analyze Fabry-Perot images for sodium and compare with [O I] 6300 Å images; assess the importance of the electron impact excitation and/or nonuniform gas distributions as a cause for asymmetric brightness distributions about Io.	

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A summary is presented for research undertaken. Papers presented at three scientific meetings and one paper to be published this month are noted. An interesting System III longitudinal dependence of the [OI] 6300 Å emission brightness near Io may be related to the System III longitudinal asymmetry in the plasma torus ion temperature. An explanation of the latter has been developed in an independently funded NASA project.

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